THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. XVII, No. 5 JUNE, 1923 WHOLE NUMBER 131

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PLATE XIII

Night View of Pasadena and Los Angeles, California, from Mount Wilson

—E. E. Barnard

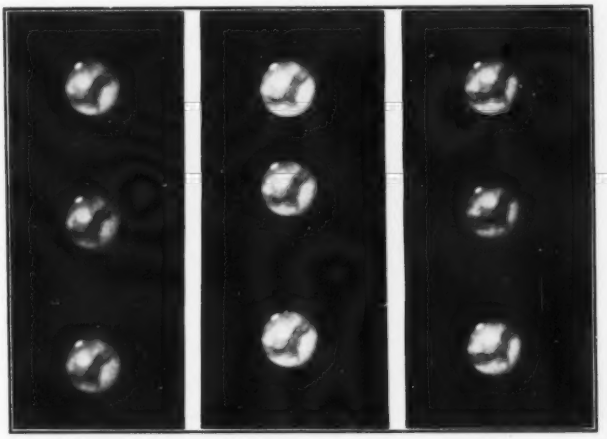
1. 2.

Photographs of the Rotation of the Earth;
Camera Stationary, Stars Trailing

1. Pointed to Equator of the Sky, Exposure 1 h.
2. Pointed to Pole of the Sky, Exposure 5 h.

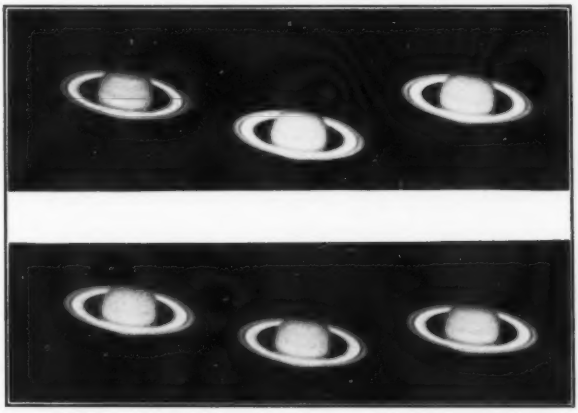
—E. E. Barnard

PLATE XIV



Mars, September 28, 1909. Region of the Syrtis Major, showing change due to rotation. 40-inch Telescope, Yerkes Observatory

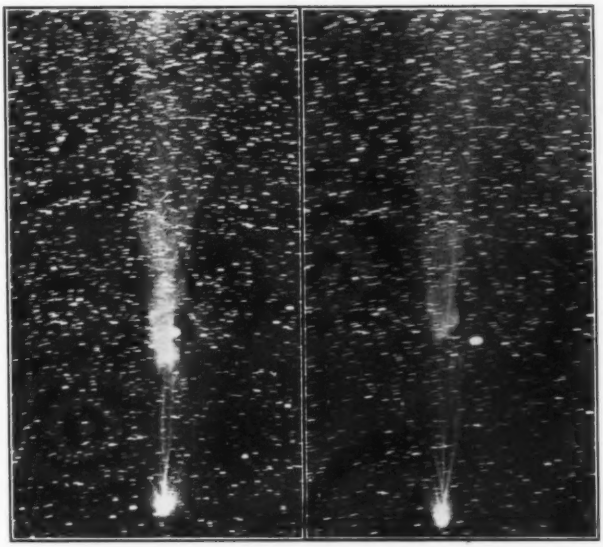
—E. E. Barnard



Photographs of Saturn, November 19, 1911: 60-inch Reflector, Mount Wilson Observatory

—E. E. Barnard

PLATE XV



8h 45m C. S. T. 13h 18m C. S. T.

Photographs of Morehouse's Comet, Showing the Rejection of its Tail
October 1, 1908, Bruce Telescope, Yerkes Observatory

—*E. E. Barnard*

PLATE XVI

Brooks' Comet, October 23rd, 1911, 16h 32m C. S. T.
10-inch Bruce Telescope, Yerkes Observatory, Exposure 1 h 15 m

—E. E. Barnard

PLATE XVII

Star Cloud in Scutum, July 30, 1905
Bruce Telescope, Yerkes Observatory

—E. E. Barnard

PLATE XVIII

The Orion Nebula
60-inch Reflector, Mount Wilson Observatory

—G. W. Ritchey

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PHOTOGRAPHING THE SKY

By EDWARD E. BARNARD

An Address before the Empire Club of Canada, Toronto, March 25, 1920

I am very glad to be here today to do what little I can in the interest of the establishment of such an observatory as the Chairman has mentioned, and which Professor Chant and other members of the Royal Astronomical Society have so deeply at heart. Though we represent two great nations we really are but one in that we are all Americans. Therefore we of the United States, where great observatories prevail, can sympathize with our brother astronomers across the border in their efforts to found a suitable observatory in Toronto. The more we study the stars together the more strongly will our friendship be cemented. The great trial we have just passed through shows how strong that friendship already is. Canadians are doing splendid work in astronomy as is seen in the observatories at Ottawa and Victoria. We may also add that one of the important observatories in the United States, the Leander McCormick Observatory at the University of Virginia, has as its Director a Canadian astronomer, Dr. S. A. Mitchell, who is doing remarkable work in the determination of the distances of the stars with the 26-inch refracting telescope of that observatory.

It must also be remembered that the late Professor Simon Newcomb, the greatest of American astronomers and one of the greatest the world has produced, was a Canadian by birth, though of good New England ancestry.

The Value of Photography in Astronomical Work

The great value of photography to astronomy lies in its power to correctly represent the forms and positions of the heavenly bodies. As an artist in black and white (and later on it will be an artist in colours also) it is unapproachable in its fidelity to nature. The most skillful human hand, though it may make a picture that closely resembles the original, and sometimes is better than the original (whether in the human face or in the beauty of the landscape) fails sadly when it attempts to delineate the features of the sky where the slightest deviation in the different pictures of an object is of vast importance if it be a true one. The photographic plate will repeat as often as you like the portrait of a celestial body and, if there is no actual change, it will constantly duplicate its first work. If there is a difference in the appearance of an object, you may know that there has been an actual change in it and sometimes the change, even though very slight, is of profound interest to the astronomer. Such a small change would be utterly masked by the errors of the most skillful artist. And it is upon such small changes that many of the most interesting and important discoveries of astronomy have been based. The human hand and eye are fallible; the photographic plate is essentially infallible. It can be misinterpreted, however, but generally some one will detect the mistake and will find from the photograph itself the true interpretation, for it can always be consulted in case of doubt. But the human hand and mind cannot be thus overhauled. They make a mistake and, in general, there is no remedy for it.

This is only one side of the question. The artist-astronomer—and he is generally of the most inferior type of artist—sees something and draws it. He fails to represent it, not because he does not see it correctly, but because he is wanting in the skill to picture what he sees.

The other side is a question of far greater importance; it is the question of what he sees and what he does not see. Manifestly the artist cannot draw what he does not see. He may, however, see it only in his mind, but that is another question. The human eye and the ordinary photographic plate see things with two different kinds of light pulsations. It is thus that we may watch

our plate develop with a light which does not affect it, while the light that impressed the image upon it probably would not affect our eye. Such a plate is highly sensitive to the ultra-violet light while the eye is most sensitive to the yellow region of the spectrum and it is by the yellow or red light that we develop the plate. Therefore if an object were shining only with the true photographic light, the eye would either not see it or would only feebly recognize it. Some of the celestial bodies (the comets and the nebulae for instance) are shining mainly with this light to which the photographic plate is so sensitive; such an object will photograph readily, though it may not be visible to the human eye. It is thus that the vagrant comet often becomes an astonishing object when it impresses its features on the sensitive plate, and shows us wonderful changes that the eye with the most powerful telescope knows nothing of. And the nebulae, though their main features are clearly seen with the eye as they are shown on the photograph, reveal to us on the picture vast extensions of feeble nebulosity that the eye fails utterly to perceive.

Thus we have two great and infinitely valuable attributes of the photographic plate in astronomical investigations, fidelity or accuracy, and seeing the unseeable. There is also the cumulative effect inherent in the photograph that does not belong to the eye. The longer the exposure, ordinarily, the more the plate sees, while the eye becomes tired and through fatigue really sees less by prolonged looking. Of course, by staining the emulsion with certain dyes, it is also possible to photograph objects to which the ordinary plate is entirely blind.

The Rainbow, a Promise for the New Observatory.

I am going to give you some pictures now, and that you may not tire too much of astronomy, I am introducing several photographs foreign to my subject. At the same time they will have a bearing on it as showing indirectly the application of photography to familiar objects, and may lead in a way to a better understanding of the real astronomical slides. They also have their purely interesting side for they are somewhat different from the general run of photographs of similar objects. (Here were introduced a picture of some clouds, and of a rainbow.) A rainbow!

The symbol of hope. Let us take this as a promise that the ambitions of our friends will be fulfilled and that the observatory at Toronto will soon be a reality. It is said that at the end of a rainbow (which end?) is always a pot of gold for him who seeks it. Let us hope that this rainbow will have a real pot of gold at its end and that it may be used to build and equip the Observatory!

The Great Canadian and other Observatories, and How the Telescope Aids the Human Eye

I am going next to show you some of the large observatories in Canada and the United States. Here is an observatory of which Canadians should be very proud and I am glad to see that it is placed in a favourable part of the world—not in an extremely cold climate, which would be unsuitable for a telescope of its size. It is the large reflector at Victoria, B.C., which is seventy-two inches in diameter and which, with the exception of one other telescope of a similar nature, is the largest in the world. Professor Plaskett has already done splendid work with it. Its very great value is shown in the fact that in photographing the spectra of the stars, where a great amount of light is necessarily thrown away on account of the prisms, Professor Plaskett can get with a few minutes' exposure satisfactory photographs of the spectra of stars (from which astronomers can tell what the stars are made of and how fast they are moving) which would require a much longer time with any of the large refracting telescopes now in use.

The great advantage of such an instrument as the one at Victoria may be better appreciated when we remember that the diameter of the pupil of the human eye is about a quarter of an inch. Therefore you will receive only the amount of light that will pass through such an aperture and any object will appear just so bright. If the pupil of the eye were larger, you would receive more light and you would see fainter objects. Now suppose the pupil of your eye were seventy-two inches in diameter; how vastly more brilliant would an object appear. This, in effect, is what occurs with the seventy-two inch telescope. All the light that falls on its immense surface (except a small amount cut out by a second small mirror) is brought to a focus at the eye and enters the pupil and falls on the retina. The result, therefore, is the same

as if the pupil of your eye were enlarged to seventy-two inches in diameter. As the amount of light thus received will be proportional to the squares of these quantities (one quarter inch and seventy-two inches) an object will appear more than 83,000 times brighter with the large telescope than with the eye alone, and you can penetrate vastly farther into the depths of space with it, for it increases the penetrating power of the eye thousands of times. And with the photographic plate (which is so much more sensitive than the human eye) and prolonged exposures, stars so faint that the eye with any telescope will never see them, are readily shown. You can, therefore, understand the wonderful advantage of this great Canadian telescope for investigating the sky and the distant inhabitants of space.

This next picture shows the home of the greatest telescope the world has ever seen. I know you will pardon the pride I take in the monster instrument (which is even greater than the Victoria telescope) for it belongs to the United States, to Mount Wilson in southern California. This great telescope is 101 inches, or over eight feet, in diameter, and what we have just said about the Victoria telescope holds with even greater force in the case of this instrument; for by the same means we find that an object seen with it will be 164,000 times brighter than with the eye alone. We have in effect increased the pupil of our eye to 101 inches in diameter, so that we can penetrate twice as far into space with it as with the Victoria telescope! This noble observatory belongs to the Carnegie Institution of Washington. Professor G. E. Hale, whose name stands among the highest in astronomy and who created this and the Yerkes Observatory, is the Director.

Our next picture shows the wonderful refracting telescope of the Yerkes Observatory of the University of Chicago. This observatory is located on the high ground about 150 feet above beautiful Lake Geneva in southern Wisconsin, some seventy-six miles north-west of Chicago. The dome that covers the instrument is the largest moving dome in the world. It is ninety feet in diameter and turns on a system of wheels by electric motors so that any part of the sky can be observed. Two large shutters cover the observing slit when the telescope is not in use. The moving part of the instrument weighs twenty tons. The

tube is pointed to different parts of the sky by electric motors and a great driving clock keeps it moving with the stars. The floor of the dome is an immense elevator, seventy-five feet in diameter, which carries the observer up and down to follow the eye end of the telescope. Professor E. B. Frost, eminent in spectroscopic work, is the Director of this great observatory.

The two telescopes of which I first spoke are called reflectors. In them the light of an object is collected and reflected by a great concave glass mirror which has a highly polished silver surface and is placed in the lower end of the tube. In the Yerkes telescope no mirror is used, but the light is collected by a lens forty inches in diameter at the upper end of the tube and brought to a focus at the smaller end where the light enters the eye. This immense tube is sixty-two feet long. The nature of this telescope is quite different from the others. Of its kind, it is the greatest in the world. It is only necessary to say that these great reflecting and refracting telescopes are mutually supplementary to each other. Each has its good qualities in which it excels. One work of the Yerkes telescope (which is done by Dr. Lee and Professor Van Biesbroeck) and of some of these large reflectors is the determination of the distances of the fixed stars, which is the first step in fathoming the depths and dimensions of our universe.

And here, last but not least in importance, is the Lick Observatory on Mount Hamilton, California, fifty miles south and east of San Francisco. It is a monument to James Lick, who gave the money for its erection. His body lies in the base of the pier of the great telescope and never had man a more wonderful monument. It has made his name famous all over the world and is constantly writing it on the sky in the lasting work done by astronomers there. The object glass of this telescope is thirty-six inches in diameter. Of the large refracting telescopes, it is second only to the Yerkes in size. It was the first of the great telescopes of to-day. The Director of the Lick Observatory is Professor W. W. Campbell, well known for his pioneer spectroscopic work. Our friend Professor Chant has imbibed some of his love for astronomy from a season's work with the astronomers of Mount Hamilton.

Photographing the Earth's Rotation

If one stands at night on Mount Wilson (six thousand feet above the sea) and looks toward the valley below him he will see what seems to be two beautiful star clusters, where the electric lights of the cities of Pasadena and Los Angeles appear as innumerable bright points. Here is a photograph of this splendid scene. (See Plate XIII.) The camera was fastened to the side of a house and the sensitive plate was exposed for one hour. This was an easy picture to make, for the lights were stationary and the camera could remain stationary also. If we look closer, however, we will see that all the lights were not stationary. Here and there in Pasadena and at other points in the picture are bright lines. These marks were made by the lights in the electric cars which were moving and thus made bright streaks or what we call "trails." This effect is interesting because, in a way, we sometimes have a duplication of it in photographing the sky, where a small planet, or asteroid as they are called, will happen to be, and by its motion leave a trail of light among the stars on the plate. If, from this beautiful scene, we look above to the star-strewn heavens, one would think that it is just as easy to photograph these stars as those in the valley. Let us see what would result. Here is such a photograph of the stars made in a similar manner to the one we have just seen, but of the real sky. (See Plate XIII.) The telescope was stationary during the exposure of one hour, but the stars have not remained stationary on our plate and are not points of light. The plate is covered with straight bright and faint lines that stretch nearly across it. These are due to the drift of the sky westward by the rotation of the earth on its axis. The telescope was pointed to the equator of the sky—to the constellation of Orion. Here is another photograph made with the instrument stationary and pointed to the pole of the heavens. In this case the star trails are sections of circles. The exposure was five hours. Had it been possible to have made it twenty-four hours they would have been complete circles. By this means we do not get a picture of the sky, but simply a photograph of the rotation of the earth. We can overcome this difficulty, however, and secure a photograph of the stars as they appear to the eye. Here is a photograph of an

equatorial telescope with a photographic lens and camera strapped on to it. The telescope is mounted on an axis that is parallel to the earth's axis and is made to rotate westward by what is called a "driving clock" just as fast as the earth turns to the east. It will follow the motion of the sky and keep every star approximately fixed in the field of view, or on the photographic plate in the attached camera.

Keeping the Stars Stationary on the Photographic Plate

But no driving clock is so perfect as to move the telescope exactly with the stars. There is always more or less irregularity of motion, all of which would be recorded on the plate, and the stars, instead of showing as points of light, would be elongated or blurred, and the fainter ones would not show because they would not be still long enough to be photographed. That is the reason why in this picture you see the observer with his eye "glued to the telescope" watching a star—a "guiding star"—which he holds constantly behind the intersection of two illuminated spider threads in the eyepiece by the slow motion rods which are controlled by his hands. Thus every star is kept immovable on the sensitive plate. If he does this carefully, every star image on his photograph will be a round point—some of them large and some small—and the finished picture will be an exact and perfect map of that part of the sky as you will see in the slide that is next shown you, which is a part of the heavens in the constellation Monoceros.

Short and Long Exposures

To help you to better understand my subject, "Photographing the Sky", it has been necessary to go into these details to indicate how the work is done. Now I am at liberty to show you some of the results obtained with these great telescopes and tell you something about the various things that are shown. To bring this more clearly before you, it must be photographic work, where the celestial body paints its own portrait. I have already explained to you that, on account of the rotation of the earth, no celestial object will remain fixed in the telescope unless the instrument turns westward as fast as the earth rotates to the east.

A driving clock is therefore absolutely necessary to turn the telescope westward to follow the diurnal motion of the sky. In the case of the sun some of the photographs of it are made instantaneously, because of its great brilliance. Here is a picture that was made in India at an observatory where such pictures of our great luminary are taken daily. At the instant of making the photograph a bird was flying between the telescope and the sun. So instantaneous was the exposure that you can see every sharp detail of the outline of the bird in its rapid flight. I show you this that you may see how brief an exposure is necessary in the ordinary photographs of the sun. Indeed it is difficult to make them quick enough. But the photographs made at night of the stars, the comets and the nebulae, are of much greater duration, and many hours are frequently given to the sensitive plate before it satisfactorily sees the faint and distant celestial body. All this time the telescope must revolve with the utmost accuracy so that the object shall not move and be blurred. No driving clock will do this unaided, but as I have explained, the observer must sit at the telescope and guide the instrument so that the images of the stars remain fixed during the exposure. Sometimes such an exposure requires the entire night, and in some cases the telescope is exactly set on the object a second, and even a third or fourth night, and the exposure continued before the faint object is satisfactorily shown.

The Sun and Its Effect on the Earth

The sun is a great spherical luminous shell, 865,000 miles in diameter, whose interior is perhaps purely gaseous. The brilliant surface which gives us our light and heat is called the photosphere. It seems to be in the nature of clouds, but not clouds formed by drops of water. What its exact nature is we do not know, because, as it is not in the form of vapour, the spectroscope cannot analyse it. Every throb on the earth is dependent upon the generous output of energy from the sun. It is, therefore, of the utmost importance that we study it constantly and find out all we can about its mysteries. It is an intensely heated body—we cannot produce any heat on the earth to equal it. This will be strikingly apparent to you when you hold your hand in the sunlight and feel its

warmth and know that the source of heat is 93,000,000 miles away! As you will see from the next photograph, this glowing surface is not always uniformly white. Frequently large dark spots, such as these shown in this picture, appear upon or in its surface. These are not permanent features, but come and go, and are due to disturbances that emanate in the sun or on its surface in the form of storms—sun storms—in which the bright surface seems to be torn asunder. That these are holes in the bright surface of the sun is the old idea of the nature of sunspots, and a very satisfactory one so far as appearances go, but those who study the sun believe it is not the true explanation of the sunspots. From all the evidence they would rather look upon them as being masses of absorbing matter. They are possibly depressions filled with cooler absorbing vapours and not holes through the solar surface.

You saw the wonderful aurora of Monday night (March 22). The cause of these auroras has been traced directly to the sun. Great magnetic storms occur there that disturb the magnetism of the earth and produce the wonderful electrical displays such as the one you saw the other night. There is a large spot on the sun now which doubtless, in some mysterious way, has had something to do with this wonderful phenomenon. From the surface of the sun great masses of incandescent calcium, helium and hydrogen gases are thrown up for great distances. Here is a photograph made with the spectro-heliograph of the Yerkes Observatory on May 29, 1919, by Mr. Edison Pettit, of an immense prominence or sun-flame which finally attained an altitude above the surface of the sun of over 400,000 miles. This photograph has been coloured to match the scarlet ray of hydrogen by which the prominences are seen in the ordinary spectroscope. They are usually photographed with the violet ray of calcium. Such photographs are truly mono-chromatic pictures.

The Moon and its Scenery

Here is a magnificent photograph of a part of the moon's surface made with the large reflecting telescope at Mount Wilson by Mr. Pease. This superb picture shows the great lunar mountain range of the Apennines (about 300 miles long) which slopes grad-

ually on the west and is precipitous on the eastern side. This range rises in sharply pointed peaks to an altitude of 15,000 or 20,000 feet, and when the sun has risen a few degrees above its horizon, the range casts a great black shadow on the plain below, serrated with many long black projections showing how slender and sharply pointed are the peaks which dominate its summit. Here is the splendid crater Copernicus, some fifty-six miles across and three miles deep, with a central cone 2,000 feet high. Below and near the north limb is the great flat crater, Plato, which seems to be partly filled with a lake of ancient lava; and here are a number of isolated mountains on the plain near it, whose black shadows are wonderfully distinct. The altitude of these mountains can be determined from the length of their shadows to perhaps a greater exactness than of similar mountains on the earth. Here are the lunar Alps and through them runs the great Valley of the Alps (a deep rift in the moon, like the Grand Canyon of the Colorado) some eighty miles long, three to six miles across and nearly two miles deep.

We say the moon is dead because it has no atmosphere and there are no changes taking place on it. Its surface is subject to intense heat in its daytime and to the bitter cold of space in the lunar night. It must also be subjected to the pitiless rain of meteoric matter from space, since it has no atmosphere like that of the earth to protect it from such bombardment. Its surface is diversified with great plains or lava beds which appear as dark spots to the naked eye, mountain ranges and great craters which are supposed to be due to volcanic agency in past ages.

The southern part of the moon, the brightest portion to the naked eye, seems to have been the principal seat of volcanic energy. It is pitted with innumerable volcanic craters, of which the most striking one is Tycho, fifty-four miles across and nearly three miles deep, with a beautiful volcanic cone one mile high in its center. At full moon many diverging bright streaks run for great distances from this crater in all directions. The nature of these streaks is not known with certainty, but it has been suggested that they may be due to a cracking of the moon's surface with the great crater Tycho as a center, and the filling up of these cracks with a more highly reflective matter from the interior of the moon.

Some of the craters in this great volcanic region are over a hundred miles in width. Some of the lunar mountains, especially in the southern part, are said to be higher than any on the earth.

We never see the other side of the moon and we know nothing as to how it looks, but we thing it must be similar to the side we do see—pitted with volcanic craters and broken by precipitous mountain ranges and vast lava fields, where no sound is ever heard and the stillness of death abides forever.

The Planet Venus Transiting the Sun

I am sure that many of you must be familiar with the brilliant planet Venus when it is evening or morning star. Its light is not its own, however, for it but reflects the light of the sun. Here is a photograph of Venus in transit across the sun's disc on December 6, 1882, made at the Lick Observatory by Professor D. P. Todd. As you see, it appears as a round black spot on the sun. These transits are very rare, the next one not occurring until the year 2004, so that no one who thus saw Venus on the sun's disc will live to see it so again. As seen in the telescope, this beautiful planet passes through all the phases that the moon does. Venus is just about the size of the earth and has a dense atmosphere. For all we know, there may be intelligent life upon it.

Mars and His Snow Caps

Here are some photographs of the planet Mars taken with the great telescope of the Yerkes Observatory. (See Plate XIV.) The white spot at the upper part of the disc is the south polar cap—presumedly of snow and ice. There is a similar one at the north pole. These white spots, during the winter of the planet, become very large and extend to middle latitudes; while in the Martian summer they melt away almost entirely. They perhaps consist of a comparatively thin sheeting of snow. In the south polar regions of Mars there seem to be mountain ranges. Their presence is revealed by the melting polar cap, which always leaves behind it, at these places, white strips that more slowly melt away. These white strips seem to be due to snow on considerable elevations. There do not seem to be any great bodies of water on the planet, but there are permanent dark regions that may be vegetation, for

they seem to undergo seasonal changes of colour. The general surface is of a yellowish or orange colour, and may consist of great deserts. Mars is much smaller than the earth, being 4,200 miles in diameter, and has a very thin atmosphere. We have no reason to believe that it is inhabited—the fact is we know essentially nothing for and little against its being peopled with intelligent life. You will see that these photographs show the turning of the planet on its axis, from west to east. This great dark spot here, called the Syrtis Major, is to the right of the center, and here you see it three hours later to the left of the center, thus showing the rotation of the planet on its axis, producing day and night. The day of Mars is about thirty-seven minutes longer than our day. It has two tiny moons that may be only ten or twenty miles in diameter, one of which goes around the planet three times in a day! Is Mars the abode of intelligent life? Is it the abode of any life? We do not know.

A World with Rings

This is a photograph of the wonderful ringed world Saturn. (See Plate XIV.) What a splendid object it is! In the telescope it appears like a golden globe (76,000 miles in diameter) surrounded by a system of great flat rings that are perfect circles. These rings are 172,000 miles in diameter; yet they are so thin that we cannot see them when they are on edge to us, a circumstance which occurs every fifteen years. This will happen again at the end of the present year. Astronomers have shown, especially with the spectroscope in the hands of Keeler, that these rings consist of multitudes of small individual bodies revolving about the planet in thin flat zones. They appear as solid rings, because we are too far away to see the individual particles, just as a sunbeam entering a darkened room with a dusty atmosphere looks like a solid bar of light until we go close enough to see the individual dust particles in it. There are two bright rings which are separated by a vacant space some 2,400 miles across, which appears as a curved dark line on the rings and is called Cassini's division. The space between the bright rings and the globe of the planet is 17,000 miles. Between these two rings and the ball is another and fainter one not shown on the photograph, which is transparent

and is known as the Crape Ring. The planet does not shine with its own light, but by reflecting that of the sun. Saturn is very liberally supplied with moons. There are known to be nine of these attendants, which range all the way from 2,500 miles in diameter to one so faint that it can be, relatively speaking, only a few miles across.

The Comets and Their Nature

The comets are the most interesting and wonderful objects that we have to deal with photographically. This is not true of all comets but applies to the larger and more active of these mysterious bodies. They shine mainly with a light to which the photographic plate is especially sensitive—far more so than the human eye. By the aid of photography we find that the comets are changing their physical appearance from hour to hour. We also find that they will sometimes discard a tail that is many million miles in length and immediately form another one in a slightly different direction which grows with amazing rapidity, while the old tail drifts away into space and is lost to the comet forever. We can imagine nothing—except nothing itself—so tenuous as a comet's tail. Several million miles of this matter will not sensibly dim the light of the faintest stars seen through it. Here are several photographs of Morehouse's comet of 1908, which was the most remarkable comet in some respects ever observed. (See Plate XV.) You can see how it entirely transformed itself from night to night, so that from its appearance you could not say it was the same object. Here are two photographs of it made on the same night and only four or five hours apart. What wonderful changes have taken place in this short interval! We would have known nothing of these extraordinary changes without the aid of photography. Some of the comets, with their tails, are thousands of times greater than the sun; yet their actual weight is so small that we have never, in any case, been able to determine it. You will notice that the stars in these comet pictures are short lines of light. This is due to the fact that the comet was moving rapidly. In making such a picture we guide on the comet's head to keep it stationary on our plate, and this throws the motion on to the stars which are drawn out into trails

of light. You remember the night picture of Pasadena. If we had moved our camera with the moving light of the trolley car, it would have appeared as a point, but all the other electric lights would have been drawn out into trails just as the stars are in these comet pictures.

Here are a few photographs of Brooks' comet of 1911. (See Plate XVI.) These show the gradual development of the tail. At first there was no tail, but as the comet approached the sun the tail developed quite rapidly until the comet became a beautiful object in the morning sky with a tail thirty degrees long. These tails always point away from the sun. In effect it is the same as if the comet were made up of a great mass of dust and gaseous matter and that a strong wind blowing out from the sun sifted out the finer particles to drive them away into space to form the tail. Though the comet probably does consist of particles comparable with dust mixed with gaseous matter, it is not a wind that blows it out from the sun to form the tail, but it is believed to be the pressure of the sun's light which produces the same effect. This accounts for the fact that the tail always points away from the sun. The spectroscope shows that these wonderful bodies are great masses of glowing vapour, shining in part with their own light, and in part by reflecting that of the sun. They consist of some form of hydro-carbon gas, of which acetylene gas seems to be the principal element, mixed perhaps with finely divided solid matter. The first of these two comets which we have just seen, contained, in both head and tail, the deadly cyanogen gas.

The Pleiades

Here is a photograph of the Pleiades. The exposure of the plate was short and it shows only what one can see in a small telescope—the seven bright stars and many smaller ones. But this is not all that belongs to the Pleiades, for this next picture, which was given a very much longer exposure, reveals the presence of an entangling system of nebulosity that binds up the principal stars of the cluster. The spectroscope shows that this matter is not gaseous. A few of these nebulosities can be seen with the telescope but most of them are shown only in photographs. Indeed all the region about the Pleiades, for an area of ten square degrees,

is involved in streaky nebulosity. Besides the bright stars, there are many faint ones connected with the cluster. The Pleiades are moving together across the sky in a south-easterly direction. This beautiful cluster is very far away from us, being placed at a distance of some 300 light-years. That is, if every star in the cluster were instantly destroyed, there would be no change in their appearance for 300 years, when the cluster would vanish from sight. Alcyone, the brightest star of the Pleiades, is many times bigger than our sun.

The Great Globular Cluster Messier 13

This is a photograph of the great cluster of Hercules. There are perhaps more than a hundred thousand stars in this cluster, in a space not so large as would be covered by the disc of the moon. Undoubtedly each of these small stars that form the cluster is a great sun. Indeed it has been estimated by Shapley at Mount Wilson that there are fifty-thousand stars in the cluster that are several hundred times brighter than our sun. He estimates its distance to be thirty-six thousand light years and that it would take a ray of light over several hundred years to cross it. These figures seem excessive and they well may be, for it is impossible to directly measure such quantities as they represent. They rest, however, upon certain reasonings that may be approximately true. However inconceivably great this distance may appear to us, it is small compared with some of the spiral nebulae, which may be several million light-years distant, according to Curtis. Some other astronomers would greatly reduce these distances.

The Milky Way and Its Stars

This is a photograph of a portion of the Milky Way. (See Plate XVII.) It shows the large star-cloud in the constellation of Scutum where millions of stars, though vastly distant from each other, are seen apparently crowded together (through their immense distance from us) like the drops of water that form our terrestrial clouds. Each one of these myriad points of light is a great sun, in many ways like our own sun, some larger than it and others smaller. If we were placed on a world about any of these distant suns, our own sun, which is but an ordinary star

of space, would appear as a small point of light just as these stars appear to us. Indeed from many of them it would only be visible in a powerful telescope, so distant are they from us. We see the sun as a large globe, but if we were to place it no farther away than the nearest fixed star, it would be only a point of light, even in the greatest telescope, and to the naked eye it would appear like a bright first magnitude star. So all these stars are vast suns shining by their own light, and our sun is but one of them. They all form an immense cluster in space and the Milky Way is but the visible effect of these stars apparently crowding together through the enormous distances at which they are placed from us. There are hundreds of millions of them, extending over an inconceivably vast region which, however, compared with space itself, is like a drop of water in a boundless ocean.

Many astronomers now believe that our stellar system, the universe of stars that surrounds us, is in the form of a great spiral not unlike some of the spiral nebulae—perhaps very much like Messier 33 whose picture I now show you and which many believe to be a vast star system like our own. Probably if we were placed near the center of Messier 33, we would see around us a Milky Way broken with star clouds resembling our own galaxy and with a sky studded with stars of every magnitude.

The motion of our sun with respect to the other stars of our system has been found to be about twelve miles a second. But as the spiral nebulae are moving with velocities as high as 600 or 700 miles a second, it is possible, if our sidereal system is really a great spiral nebula, that it may be rushing through space carrying our sun with it with a speed of several hundred miles a second.

Some of the Nebulae

Here is a photograph of the planetary nebula Messier 97, the so-called "Owl Nebula" of Lord Rosse. It is an immense globular mass of gaseous matter, perhaps many times larger than our entire solar system. It is one of the best examples I know of for illustrating the value of the photographic method, over that of the human eye and hand, in giving us an idea as to how these objects really appear in the sky. You will see that the photograph shows us an enormous globe of luminous gas rather sharply

defined in its outlines, having in it two dark spots with no stars in them but with several small stars near. Here also is the Rosse drawing of the same object which is very extraordinary indeed, but as you will see, it does not look much like the photograph. In each dark spot shines a considerable star, making them look like two eyes. Fringing the outlines of the nebula is a system of whisker-like rays. These and other marks give it a most ghostly and solemn look. From these features, so curiously drawn, it was quite appropriately called the "Owl Nebula". But let us turn this picture upside down. (Slide reversed.) What a horrible, bewhiskered, fiendish face we have here, with a grin that certainly could only belong to the nether regions. It needs but a pair of legs to execute some horrible dance in space. Perhaps Lord Rosse's observers drew it with the other side up, we do not know. But it was an honest effort to show how the object appeared in the great telescope at Parsonstown. With the most powerful modern telescopes we do not see these grotesque features. What we do see agrees with what the photograph shows and what really exists in space.

This is a photograph made by Ritchey with one of the large reflecting telescopes at Mount Wilson of the great nebula of Orion. (See Plate XVIII.) This object is a vast mass of gaseous matter. It is shining by its own light and the spectroscope shows that it consists of various gases, principally hydrogen and helium and an unknown gas called nebulium and not yet found on the earth. How soft and beautiful is its light! How restful and quiet this immense object appears to be! And yet the work of Fabry and Buisson, which has been verified by Professor Frost at the Yerkes Observatory, shows that the nebula is a seething mass of gaseous matter where there is no rest and over whose vast bulk relative motions of several miles a second are constantly taking place. Yet it is so far away that these rapid and large changes, which must occur in it, will require a great lapse of time before they actually become large enough to be seen from the earth. Its distance from us is so great that it has been estimated that it would take its light, travelling at the rate of 186,000 miles a second, a thousand years to reach us. One of the component gases of this mighty nebula is called helium, so named because it was first found in

the sun. It will take but a moment to tell you briefly the history of our knowledge of this wonderful gas which partly makes up this splendid nebula and which promises to be of such tremendous importance to the human race.

The Story of Helium Gas

At the total eclipse of the sun on August 17, 1868, Janssen, the celebrated French astronomer, found a bright yellow line in the spectrum of the solar prominences, near the well-known sodium lines, indicating the presence of a previously unknown gaseous element. This being the first that was known of this element it was, as we have said, called helium. Efforts were made to find this rare substance on the earth but for many years without success. In 1895, however, Sir William (then Professor) Ramsay, in examining with a spectroscope the gas obtained from a rare mineral from Norway, called cleveite, discovered the presence of a bright line in its spectrum which seemed to be identical with that of helium. This gas was found later in other places, especially in some of the mineral springs of Germany. Two German physicists, Runge and Paschen, on investigating its presence found that the line produced by it was double, a bright line and a faint line, while that of helium in the solar spectrum seemed to be single. This fact made it appear doubtful if the new substance really was the same as that found in the sun. Professor Hale, then beginning his career as a young astronomer in Chicago, hearing of the doubt cast upon this discovery, at once examined this line in the spectrum of the sun with the powerful means at his command. Fortunately there was a brilliant prominence or sun-flame (in which helium shows its presence) then visible projected above the sun's surface. Under careful examination he saw that the helium line was really double—a bright and a faint line! Thus was established the identity of the substance found by Ramsay with that in the sun. In reality there are many other but less conspicuous lines due to helium. Later this gas was also found to be present in the nebulae and in some of the stars, which from this fact are called helium stars. As time went on helium was found to be rather abundant on the earth, especially in connection with certain oil wells in Texas and elsewhere. Singularly enough it

is also found to be non-inflammable and to have a lightness or lifting power but little less than that of hydrogen. Recognizing the immense importance of this gas for balloon purposes in the great war—for balloons filled with it could not be set on fire by incendiary shells or other means, which is the great weakness of the hydrogen balloon—the United States government erected large plants in some of the oil regions and put its experts to work to produce this wonderful gas in large quantities. So successful were these men that when the armistice was declared there were great stores of this precious substance on the Government docks ready for shipment to France. And to show how the war, while it greatly increased the price of things in general, made at least one thing less expensive, Professor Moore, who was put in charge of this department, states that before the war helium gas could only be produced at an expense of some two thousand dollars a cubic foot but at the close of the war it could be made at a cost of only ten cents a cubic foot.

In conclusion I wish to thank you for your patience in listening to me.

Yerkes Observatory, April, 1920.

DOMINION OBSERVATORY WORK IN THE MACKENZIE DISTRICT

By A. H. Miller

THE work of the Dominion Observatory in the Mackenzie River district, during the last two years, affords at least one illustration of the fundamental part that astronomy plays in the survey and the accompanying development of such a large country as Canada.

The work was begun in the season of 1921 at the request of the Topographical Surveys Branch of the Department of the Interior. Following the discovery of oil about 60 miles below Norman on the Mackenzie river, the necessity at once arose for surveys to locate the numerous claims that were subsequently staked. It would have been too great and too expensive an undertaking to extend so far north in such a short time the meridians and base lines which in Western Canada form the control for subdivision surveys and traverses. On the other hand it was most desirable that the surveys in the far north should be linked up with the existing surveys in Western Canada. Consequently it was decided to run a stadia traverse from the most convenient northerly point in the existing surveys right down to the oil fields. The part of the Dominion Lands survey that was chosen from which to begin the traverse was the point where the 30th base line crosses Slave river. This is about 65 miles up the river from Fitzgerald at the head of Smith rapids and the approximate latitude of the point is about 59° 08′. From here to the oil well below Norman the distance is nearly one thousand miles. In running such a long traverse it is only to be expected, in spite of the most careful work, that small errors will creep in and that their effect may accumulate as the survey progresses. In order to correct these errors and to prevent their accumulation certain suitable points in the course of the traverse were selected at which the latitude and longitude were to be determined. The traverse was "tied in" to these points as it proceeded and the position of all points along the survey are

therefore referred to the geographical positions of the selected points.

It was the task of the observatory to determine the latitude and longitude of each of these control points. During the season of 1921 the survey was carried down the river as far as the Sans Sault rapids, about one hundred miles below Norman. The control points selected were Resolution on the south shore of Great Slave lake near the mouth of Slave river, and Providence, Simpson and Norman on the Mackenzie river. The positions of these points were established in the summer of 1921 and points as far down as Arctic Red river were established the following season to provide for the required extension of the survey to the Delta of the Mackenzie.

Owing to the fact that most of these places are several hundred miles from the nearest telegraph station, the usual method of determining the longitude by exchanging signals over the wire could not of course be employed. Instead of this, time signals that are sent out by wireless from several stations were made use of. The time signals which were used in the work were those from Annapolis, San Francisco, San Diego and Panama.

In addition to the determinations of latitude and longitude, a determination of the force of gravity was also made at each place.

The field party consisted of the same members of the observatory staff for the two seasons. Mr. A. H. Swinburn took the star observations that are required for obtaining the latitude and longitude. For this purpose he was supplied with a two-inch astronomical transit of the "broken" type and fitted with a transit micrometer. He was also supplied with a chronograph for recording the time of transit of the stars in terms of a chronometer. At each station a cement pier was built on which to place the transit while the observations were being made. (Another cement pier had also to be built for the gravity apparatus.) Usually three or four nights were devoted to the observations for time or longitude and using Talcott's method forty pairs of stars were generally obtained for the latitude determination. Including the time required (usually about two days) to get the station in readiness, to complete these observations required as a rule from ten days to three weeks. This length of time, of course, depended entirely

on the weather. During the summer one is at a great disadvantage in taking these observations, as in that part of the country from latitude 60° to the Arctic circle there is only a brief interval during the twenty-four hours when it is not too light for good observing. Very often even in the finest summer weather, this period of partial darkness is marred from an observing point of view by mists which collect very soon after the sun has gone below the horizon. This is possibly due to a considerable change that takes place in the atmospheric temperature shortly after the sun goes down and to the abundant supply of water in lakes, rivers and muskegs, some of which is no doubt absorbed into the atmosphere under the influence of the glaring sun of the day.

The receiving of the wireless signals was attended to by Mr. J. P. Henderson. He also had difficulties to contend with. Owing to the great distances from the sending stations and the almost continuous daylight, static disturbances gave a considerable amount of trouble. It was therefore necessary to set up the wireless apparatus to the very best advantage. Although at points farther down the river it was not possible to get very much of the press news sent out by wireless, Mr. Henderson was very successful in getting the time signals from the various stations, which were absolutely necessary for the successful completion of the work. At the times the signals were received they were compared by the method of coincidences by extinction with a chronometer which was set to gain about one second in every hundred seconds on the mean time signals. As the signals last for five minutes there are ordinarily at least three times during the five minute interval when the second beats of the signals coincide with the beats of the gaining chronometer. It is possible by this coincidence method to make a time comparison to within a hundredth of a second. This chronometer was compared on the chronograph, each time just before and just after the receipt of the signals, with the sidereal chronometer used by Mr. Swinburn in his star observations. In this way the sidereal chronometer time of arrival of the signals at any particular station was determined to within perhaps a few hundredths of a second. As the sidereal chronometer was in turn compared (also on the chronograph when the star observations were made) with the time of transit of the stars, it was finally

possible to determine the arrival of the wireless signal in terms of the sidereal or local star time at the place of observation. The same signals that were received at the field stations were also received at the observatory at Ottawa and their time of arrival was compared with the standard Riefler clocks of the observatory. The variations of these clocks from the local sidereal time at Ottawa are determined very accurately from the regular observations that are taken with the meridian circle. The local sidereal times of the same time signals were therefore determined both at Ottawa and at the field station. After allowing for the time of transmission of the wireless signal (about one hundredth of a second for 2000 miles) the difference between these local times for the arrival of the same signal gives the difference in the longitude between Ottawa and the field station.

The gravity observations were made by the writer. They were made with a half-seconds (invariable) pendulum apparatus which has been in the possession of the observatory since 1902. Very little difficulty was experienced in making satisfactory determinations. As the pendulums are bronze and have a large temperature correction it was first necessary to secure a building in which the variations of temperature were not too large nor too irregular. The log buildings that were readily placed at the disposal of the observer by the Hudson's Bay Co. at all of the stations with the exception of Resolution made very satisfactory temperature rooms. At Resolution Bishop Brenyat of the Roman Catholic Mission very kindly gave the writer the use of a good log building and at the station on the Liard river, which was occupied during 1922 and is thirty miles from the nearest settlement, a log hut was built by the party in which to set up the apparatus. The only other large correction that has to be applied to the observed times of vibration of the pendulums is that which must be made to take account of the rates of the two chronometers that are used to determine the periods of the pendulums. A variation of one second in the daily rate of the chronometers produces an apparent change in the period of the pendulums equivalent to that which is produced by a change of about one and a half degrees Centigrade in the temperature of these pendulums. If an error of this amount were made in determining the rates of the chronometers the observed

value of gravity at the station would be in error by more than twenty times the possible accuracy of a determination, which is at best about one thousandth of a dyne. It is therefore one of the most important things in pendulum work to have the rates of the chronometers, that are used, determined as accurately as possible. For all the stations during both seasons the wireless signals from Annapolis, Maryland, were used for this purpose and their use has proved highly satisfactory. The comparisons with the signals were made by Mr. Henderson and he rendered very material assistance during the progress of the gravity observations by being generally able to supply the writer with preliminary values of the chronometer rates a few hours after the time comparisons were made. The results of the gravity observations taken in 1921 have already been published and a report on the work for the two seasons is at present being prepared.

The time comparisons at Ottawa were made by Mr. W. A. Dier and by Mr. R. Meldrum Stewart. In addition to his other duties the latter had immediate charge of the direction of the work as a whole.

Transportation

Although the season of navigation in the north is short, it is surprising with what ease and comfort one can travel to the Arctic and back by the Mackenzie river. The regular route is now by McMurray on Athabaska river. From here by Athabaska river, Lake Athabaska, Slave river, Great Slave lake, and the Mackenzie river to the Arctic there is only one obstruction to navigation,—the Slave rapids between Fitzgerald and Ft. Smith, where a portage of sixteen miles has to be made. Except in continued wet weather the road across the portage is good and motors are provided to take passengers across. With this exception the whole of the trip can be made in large, comfortable boats. The round trip from Edmonton to Aklavik in the Delta of the Mackenzie can now be made in about one month's time.

The length of the season of navigation is, in the spring, controlled by the ice in Great Slave lake which does not break up until the latter part of June, and in the autumn by ice which forms early in October in the shallow waters such as the west end of

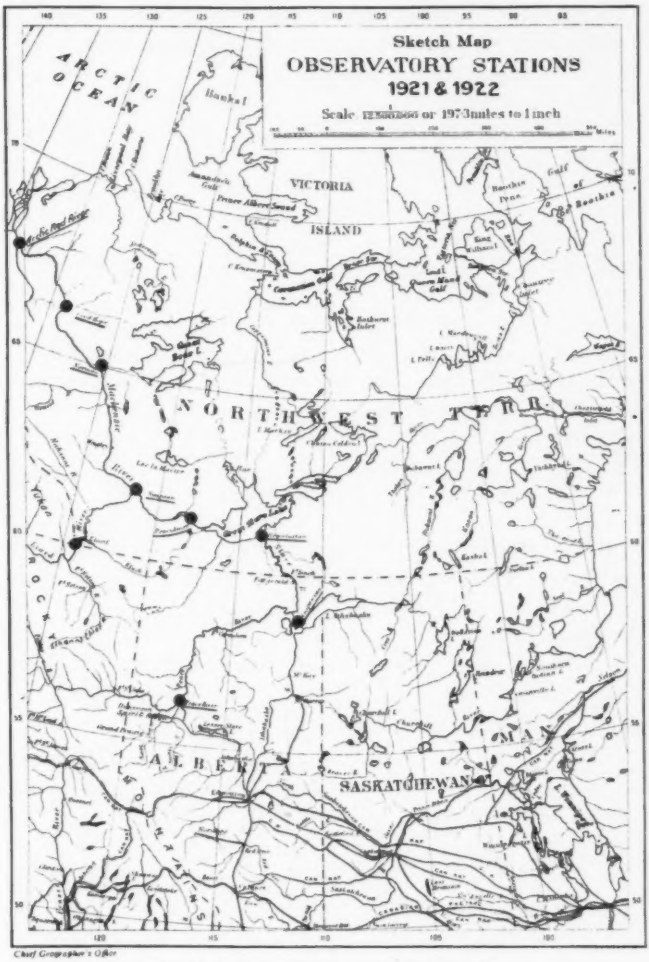
Lake Athabaska. As a result of this, after allowing for travelling time, not much more than two months can be counted upon for actual work along the Mackenzie during the summer season.

Expedition of 1921

During the season of 1921 the observatory also established a station at Peace River in addition to the four other stations farther north. This station was occupied first. Instead of depending on the wireless signals for determining the chronometer errors, at Peace River, use was made of the observatory clock over the telegraph wire from Ottawa. The errors determined by both methods were of course compared, and for the gravity work independent determinations were made using both methods. The results were so satisfactory that it was decided to use the wireless in making the gravity determinations at the other stations in the north. At these stations there was the alternative for the gravity work of rating the chronometers from the star observations. However there was a great advantage in using the wireless as the rates could be determined at least twice a day quite independently of uncertain weather conditions that might prevent any star observations being taken at all.

The trip to the north was begun on June 4th when the party left Peace River by the steamer *D. A. Thomas* for Vermilion Chutes. At the lower end of the five mile portage at the Chutes we were met by another steamboat which took us on to Fitzgerald. This place was reached on June 8th.

Both these boats are, like most of the boats in the north, woodburners. Cordwood is cut (usually during the winter) and piled along the river at suitable places for the steamer to stop and take on fuel as it is required for the trip. By north country navigators this is known as the process of "wooding up", and usually has to be done once or twice a day. It was while wooding up on the Peace that the observatory party first discovered that there were mosquitoes in the north in great numbers. This is one of the great discoveries that, recalling the words used in making treaty with the Indians farther north, promises never to be much in error: "As long as the sun rises in the East and sets in the West and as long as the waters flow to the North". Certainly they were



Map showing route taken and stations occupied.

quite as numerous during the season of 1922. In order to counteract the activities of the mosquitoes during the night, when like other criminals they are usually most active, one takes with him a mosquito bar. This is a sort of rectangular box of cheese cloth which can be supported by sticks over one's bed. While camping it is the only way during the summer, unless one has a mosquito proof tent, of being assured of any rest at night. Later on, at Providence, in the early part of July the party made the acquaintance of another quite friendly but very objectionable creature—the "bulldog". How long he has flourished in the north country it does not seem possible to determine. Certainly he predated the memory of the oldest inhabitant. There is, however, a record of his existence in the north of Europe as far back as 1736. For de Maupertuis, who was commissioned to make the expedition to Lapland to test the rival theories of Newton and Cassini regarding the flattening of the earth, speaks of being "tormented" in that country by "great flies with green heads, that fetch blood wherever they fix".

After crossing the portage from Fitzgerald a delay of over a week had to be made awaiting the departure of the first boat down the river. Finally on June 17 the party left by the *Lady Mackworth* (a gas-boat of about 150 horse-power). Great Slave lake was reached the following day and after waiting here for more favourable weather we proceeded on to Hay River at the west end of the lake and thence to Providence, our first station, which was reached on June 21. The things that impress one most in crossing Great Slave lake for the first time, at this time of year, are the numerous mirages that are to be seen and the truly wonderful colouring of the sky that lasts practically from sunset to sunrise.

As we were among the first to reach Providence we received an even heartier welcome from the inhabitants than usual. However the hospitality of the white men of the north country is at all seasons of the year unbounded and the writer has good reason to feel very grateful to them on this account and for the very great assistance he received on every hand in carrying on the work with which he was entrusted.

As at all stations, the first thing on the programme after reaching Providence was to select a suitable building in which to take the gravity observations and at the same time a suitable spot near at hand for the astronomical pier. This having been settled, the next thing was to get sand and gravel for the piers. On account of the absence of any kind of transport this had to be carried to the station on the back. As about two tons of material were usually required for the piers, this, together with the mixing of the cement, entailed no small amount of work. With few exceptions sand and gravel could be had at the river's edge and it was then only necessary to carry it up the steep bank to the station which was naturally chosen near by. As a rule the piers were completed in about two days. During this time over a ton of equipment was also brought up from the landing and the camp started going. Several hundred pounds of provisions had also to be carried up to instal the cook in his quarters, who while these provisions were on land had to be prepared to carry on an everlasting dispute with the hungry husky dogs regarding the ownership of such things as bacon, lard, etc.

At several of the stations it was possible to get Indians to do the packing and at some places they could be trained to the occupation new to them of mixing cement, an operation in which they took an almost childish interest and amusement. However the Indian is not nearly so satisfactory an employee as the white man; even when we were fortunate enough to enlist his services a great deal of the manual labour had still to be done by members of the party.

When the piers were completed and the instruments set up the hardest part of the work at a station was done. Quite often the time that had to be spent subsequently in taking the observations was rather monotonous. However this was not the case at Providence. Here there was excellent fishing to be had in the river. The first court of law ever assembled in the North West Territories was in session at this time at the old mission church. At the same time a treaty was made with the Indians of this part of the country by the late Mr. Conroy of the Indian Department. This was a very interesting event in itself and although the Indian is unlikely to ever have a better friend than Mr. Conroy it took two

VIEWS ON THE EXPEDITION
Above: Erecting the Astronomical Pier at Providence, June 23, 1921.
Below: Bear Rock, from Norman, August 18, 1921.

or three days' parleying before the Chief and head men were ready to sign the treaty.

This brought a great number of Indians (and unfortunately for our cook their dogs as well) to the post. Although one got very tired of the entertainment in time, to watch their nightly dances in which all from the very old to small children take part was quite a novelty to us at first and not without considerable interest. They are held in the open and last till sunrise. The movement consists of a general shuffling in a circle, the size of which depends on the number of dancers (who may fall in or drop out at will). The music is supplied by the voices of the dancers themselves and there is very little variety to it. The other chief form of amusement of the natives, although it is not so generally indulged in by all, is gambling. The stakes range from a small box of matches to a plug of tobacco and the game usually lasts the most of the day. With the beating of the drum that accompanies it and the continual shouting of the enthusiastic players the game can be heard for some distance.

At Providence we had some of the poorest observing weather of the season and it was not till July 16 that we were ready to leave on a sixty-foot scow that had been brought down from Peace River for us by the Topographical Surveys Branch. Mr. F. V. Seibert, who was in charge of transportation for that branch, happened to be in Providence at the time, and, in keeping with the fine co-operation that has existed between representatives of the different government departments carrying on work in this part of the country, hitched his 6 H.-P. motor canoe alongside our scow and took us down to Simpson, a distance of 160 miles in twenty-five hours.

Our work at Simpson was completed in exactly two weeks. We left for Norman a little after midnight on July 31. For the first fifty miles of the three hundred miles between these places we again had the motor canoe. But beyond this we proceeded by simply letting the current take us down stream. Norman was reached in three days. Our average rate of travel was therefore one hundred miles per day. Cooking was done on board and no stops were made at night. Owing to the fact that we had almost perfect weather for this part of the trip, and as the fly season

had already come to an end, drifting down the river in the scow from Simpson to Norman was one of the most pleasant experiences the writer has ever had.

The work at Norman was completed in due course, after which on August 26th the party took the first steamer back to Resolution. The trip upstream from Norman to Resolution occupied eight days, and as all the government parties still working in the country were on board it was naturally a very pleasant voyage. The journey was broken for two weeks to establish the stations at Resolution. After this we returned by the usual route to McMurray. Edmonton was reached on October 1st.

Expedition of 1922

Owing to the fact that a station on the Liard river, where the 60th parallel crosses it, was on our programme for 1922, it was decided this season to enter the district by the Liard River route. In addition to this station, others were also established, during 1922, at Good Hope and Arctic Red River on the Mackenzie. On the way home a station was also occupied at Chipewyan on Lake Athabaska. The astronomical station on the Liard is a most important one as it establishes for the first time the boundary between the Yukon, the North West Territories and British Columbia at this point.

The outgoing journey was made from Spirit River, on the E. D. & B. C. railway, by wagon for about 100 miles to within a few miles of Ft. St. John on Peace river, and from there by pack horse for about 150 miles to a branch of the Fort Nelson river known as the Sikanni Chief river. Here the summer provisions for the party and their instruments had been hauled in by sleigh during the winter. At this place a thirty-foot scow was built, in a few days after the arrival of the party, from lumber that had been whipsawn on the spot by four men who were stationed at the cache during winter by the Topographical Surveys Branch. The remainder of the trip was made in this scow down the Sikanni Chief and Ft. Nelson rivers to the Liard. A stop of about three weeks was made to establish the station on the Liard, after which the party proceeded down the Liard to the Mackenzie and thence down the Mackenzie to Good Hope and Arctic Red River, about

sixty miles north of the Arctic circle. In all, the distance travelled by scow from the Sikanni to Arctic Red River was about thirteen hundred miles. Two "Evinrudes" were attached to the scow to give steerage way and at Good Hope a motor-boat was hired to use with the scow in the trip from there to Arctic Red River (a distance of about two hundred miles).

While the trip across the portage from Ft. St. John to the Sikanni was a fairly strenuous one it was nothing compared with some of the strenuous days the party were to experience later on. For about eight days, or for a distance of about two hundred miles from the cache on the Sikanni, navigating the scow was the hardest kind of work. The water in this part of the river was fairly low at the time (the first week in June), but the current was still very swift. Consequently it was impossible to avoid being landed high and dry on some of the numerous gravel bars that there are in the upper part of the river. As we had a load of about three tons on board and for this part of the trip there were only three of us to handle the scow, getting off our average of about three bars a day monopolized about half our time and used up all our energy. Further, there were worse things to contend with than the gravel bars. The Sikanni Chief and the upper part of the Ft. Nelson river are lined with piles of driftwood that accumulate in the bends of the stream. Sometimes one is slammed into these piles by the current and it is not always possible to get away without incurring damage—usually a hole punched in the side of the scow. The most troublesome things of all were what are known as "sweepers". This is a rather descriptive name for trees of all sizes that have fallen into the river due to the wasting away of its banks. Sometimes the whole channel is almost entirely blocked with them. They are usually found close in to shore anchored to the bottom by their roots but owing to the action of ice and water they may be encountered in any part of the stream even in the centre. In swift water they are liable to upset almost any kind of craft.

From about twenty miles above Ft. Nelson the whole route is easily navigable right down to the Arctic ocean. It is true there are about ten miles of rapids in the Liard just above Simpson and there are the Sans Sault rapids in the Mackenzie, but both are easily navigated provided the proper channel is taken. Although

we were somewhat delayed by persistently strong upstream winds which in the wide stretches of the Mackenzie create quite heavy seas, the whole trip from Ft. Nelson to the Arctic was made without the slightest trouble.

Outside of the very great interest of such a trip, as viewed from almost any angle, there was much to compensate from a scenic point of view for any discomforts that were experienced. The Mackenzie river itself is one of the finest streams in the world and from Simpson to the Delta it can boast of much fine scenery along its course, of which may be mentioned the country along the river where the Rocky Mountains are crossed, Bear rock at Norman, and without any doubt one of the finest views in the world is that of the Ramparts of the Mackenzie just above Good Hope. There is also some very fine scenery along the Liard in the mountainous region below Ft. Liard. Nahanni Butte at the entrance of the South Nahanni is also a sight that once having been seen will not soon be forgotten.

The work at Arctic Red River was completed on August 27, following which the party were brought out by gas-boats of the Alberta and Arctic Transportation Co. to Chipewyan and later to Waterways the terminus of the Alberta and Great Waterways railway from Edmonton.

The distance covered in the round trip from Edmonton, of which about 650 miles were by rail, was about 4000 miles and took about five and one-half months to complete.

POPULAR ASTRONOMICAL PUBLICATIONS

By Albert R. Hassard

MANY people frequently inquire in regard to the best books which tell in a popular manner of the facts relating to astronomy which are inquired into constantly by masses of people. While, in reference to other subjects, lists of useful books are often published, I am not aware that there is any useful list of astronomical publications to which reference may readily be made. It may therefore be of interest to have a list of astronomical publications at hand to which beginners or novices in the study may be referred, as furnishing them with information upon one of the greatest and most wonderful of the sciences, and which will draw the newcomer into the realm of astronomical investigation upon a pathway both enchanting and instructive.

Many years ago a minister named the Rev. Dr. Thomas Dick, whose pen was busy both scientifically and morally, wrote several volumes on astronomical themes. In some instances these have been collected all into one volume. In other instances the books are published separately, and, of course, under separate titles. Among them are "Celestial Scenery," "The Sidereal Heavens," and "The Practical Astronomer." Although the latest of these writings is nearly eighty years old, still it, as well as the others, contains some information of an elementary nature, and written in a most entertaining manner, that render them even yet prizes in the hands of the most scholarly astronomers of the age. Of course, much that they contain has been superseded by the results of later investigations, but their finished literary style, their wealth of both pictorial and literary illustration, and their wide penetration into a mass of previously unpublished information, render them of such general value that it will likely be long indeed before they are entirely banished from the astronomical libraries of the world. One or more of these books ought to be the beginner's text-book on the subject.

Another writer, Miss Agnes M. Clerke, is one whose contributions to astronomical study should not be overlooked. She has written several volumes, and while they are quite large, at the same time they furnish very easy reading, inasmuch as they quite carefully avoid technical language that is unfamiliar to so many, and facts are stated with a large amount of popularity in the use of language. She is a comparatively recent writer, and in matters of popular interest there is little need of revision of any of the more important matters which she has so ably and carefully discussed. Her writings should give a beginner a wide and comprehensive knowledge of astronomy, to say nothing of setting the mind upon tracks of inquiry into new and hidden things which stretch out into the vast and hitherto unexplored realms of space, and far onward into the veiled vistas of eternity. Besides the "History of Astronomy during the 19th Century," she has written "Problems in Astrophysics" and "The System of the Stars."

A writer who is still living, and who is a practical astronomer of world-wide renown, and who, although a writer in the French language, is as well known in English-speaking countries as in his own, is the famous Camille Flammarion. I am not in any way familiar with his writings in their original language, but in common with many others I can testify that there are few writers in the English language whose writings have the literary splendour burning through them which constantly flames through his magnificent and coruscating pages. Flammarion is now eighty years of age, and has been a lecturer and writer on astronomical subjects since he was twenty—sixty years of unbroken teaching in his own unexampled way. Among his books, which are everywhere highly popular, are the following: "The Plurality of Inhabited Worlds," "Studies and Lectures in Astronomy," "The Atmosphere," "The Planet Mars," and "Popular Astronomy."

A writer who has contributed in an important way to astronomical knowledge is Sir Robert Ball, who at one time held the high post of Astronomer Royal to Ireland. About the year 1905 he published a new edition of his famous book, "The Story of the Heavens." This edition is printed in a large and clear type, on excellent paper, and contains eighteen large, full-sized coloured plates of sun, moon, planets, comets, and other celestial wonders,

as well as over one hundred illustrations of instruments, observatories, stars, and countless other wonders, which are a never-ending source of interest to those who are deeply interested in the subject. He discusses in very easily understood language many of the elementary problems about which so many thousands of questions have been asked through the ages, and his book to the astronomical beginner is almost a condensed library of the entire subject. "Is Mars inhabited?" "Are there people on the other planets or stars?" "How vast is the universe?" "How large are the stars that we see in the sky?" "Are we ever in danger of being annihilated by any of the comets?" "What are comets made of?" and many other entrancing subjects are popularly although briefly discussed by this erudite writer, who, during a long and industrious lifetime, was such an ornament to his profession. Sir Robert Ball also wrote "Star-Land," and other books as well, any one of which cannot but be of deep interest to the student of the boundless story of the ever wondrous skies.

A writer who on the American continent has perhaps more than any other done a world of work in popularizing the subject of astronomy is Richard A. Proctor, whose numerous books, each treating of a single aspect of the science, have been read throughout the world during the past half-century. A list of his writings, all of which have been written exclusively for the technically uninformed reader, forms a miniature library. Mr. Proctor was a singular figure in the realm of science. He was a noted musician, an expert chess player, a finished athlete, a world-renowned whist player, a successful editor, a tireless contributor, and a scholar of the like that there are few in either England or the American continent. Although born in England, he came to America in middle life, and lectured and lived there until his death in 1888 in New York City. He wrote and published fifty-seven books, most of them of an astronomical nature. To anyone who must learn his little all of astronomy in a few brief and easily understood books, Mr. Proctor's volumes will form no disappointment. Here are the names of a few of the books on that subject which he has penned: "Saturn and its System," "Other Worlds than Ours," "Half Hours with the Telescope," "The Sun," "The Moon," "The Orbs Around Us," "Other Suns than Ours," "Borderland

of Science," "The Poetry of Astronomy," "The Universe of Suns," and one may add to these "and others," with a confidence that the "others" are just as entertaining and as important as those of which mention has been made.

Mr. George F. Chambers' "Handbook of Astronomy" is a very pleasant book on this interesting subject. He is also the author of some other works as well; one dealing with the atmosphere, another with the weather, are of very considerable interest.

Professor Simon Newcomb, while not in any sense a voluminous writer, has published a number of contributions to astronomical lore. For many years he was responsible for the annual publication of the United States Naval Department, known as "The American Ephemeris and Nautical Almanac." This is the American edition of the book bearing a similar title and published annually in England, by the authorities at the head of the Greenwich Observatory. These two publications contain immense numbers of tables replete with all the information that mariners and others require in the calculation of places and dates throughout the world. These books are published about three years in advance, that for 1925 being now available.

Mr. Garrett P. Serviss has published some excellent works on Astronomy, among them being "Astronomy with an Opera Glass" and "Around the Year with the Stars." One might also mention "A Field Book of the Stars" by W. T. Olcott and "A Beginner's Star-Book" by Kelvin McKready.

For more advanced inquirers into the wonders of the Heavens, the Rev. T. W. Webb's two-volume publication known as "Celestial Objects for Common Telescopes" is practically invaluable, and a companion work to it is Mr. Geo. F. Chambers' edition of Admiral Smyth's "Bedford Catalogue" of stars. These writings go over almost the entire Heavens, and pick out stars and other celestial objects which are of more than ordinary interest, and tell much about them, their astronomical history, their location, their movements, their magnitudes, their companions, and whatever is romantic or of real interest regarding them. These books are rather books of reference than books to be read as one would read a work by Proctor, or Flammarion, although on the principle that a man used to turn for relaxation from the reading of novels

to the perusal of his Webster's Dictionary, perhaps Webb and Chambers may be read with some interest as continuous stories.

One who wishes to pursue the study of astronomy should be provided with a good map of the stars. There are many of these in existence, but my own preference is "Proctor's Star Atlas." Not having been able to secure a copy of this book when I wanted it, I obtained sheets of paper the same size as the maps in that book, and made a copy of eleven of the large maps which that book contains. The twelfth I did not copy because it was a map of stars around the south pole, and as these are not often referred to in Canada, because of their permanent invisibility in regions much north of the Equator. I believe copies of the work can now be obtained. Other atlases are by Klein, Norton, Peck and Ball.

Our own Royal Astronomical Society of Canada publishes annually an astronomical "Handbook," which contains within small compass invaluable information relating to the expected astronomical events of the ensuing year, together with much other information, not always to be found so conveniently assembled. This publication is an annual gift to all members of the Society, and its value cannot be over-estimated whether in the hands of novice or expert. The JOURNAL of the Society published periodically and containing both expert and popular information is invaluable to all interested in the subject.

Most libraries, even in small towns, contain one or more of the writings mentioned in this article, and the perusal of any of them, or more if possible, should prove to be of more than momentary interest to anyone who wishes, even amidst the pressure and perplexity of active life, to lift the eyes and the thoughts skywards, and read some of the marvellous wonders of the vaulted Heavens in the twinkling visitors of the sunless hours that reign above us.

ASTRONOMY A NATIONAL NECESSITY*

By R. J. McDiarmid

ASTRONOMY can claim perhaps the first place in science, with regard to age at least. Science so far as we know had no existence before the beginning of history, that is about 6000 years ago, and until about 3000 years ago it occurred in only rudimentary form.

The science of astronomy has had a gradual development through the ages. It is true that we can trace a great many of our present ideas back many hundreds of years. To the early Egyptians we owe but little, but to the early peoples who lived in the valley between the Tigris and Euphrates rivers in Mesopotamia we owe a great deal. The Egyptians were sun worshippers; the explanation for this, no doubt, is partly due to ideas adopted by them for measuring the period of their year. The Nile river passed flood tide with marked regularity. At Memphis and Heliopolis on the banks of the Nile, seat of civilization 3000 B.C., this event occurred about June 21st. This meant the inundation of the land, followed by seed time and harvest, and marked the beginning of a new year. It was quite natural then to associate the sun's position in the heavens with the beginning of the year and eventually their year dated from the time of summer Solstice, that is the time when the sun has its maximum northerly declination, or, in other words, is nearest the zenith, which occurs about June 21st. The astronomical phenomenon observed by their priests for this event occurred when Sirius, the dog star (*i.e.*, the bright blue star south and east of Orion), first appeared in the heavens as a morning star, which occurred on June 21st at Memphis. The fact that many of their pyramids and temples were oriented with reference to the point at which the sun rose on the day of summer solstice (that is the first day of a new year), no doubt had a distinctly religious bearing. Their year consisted of twelve months of thirty

*Address given February 13th before Ottawa Centre, Royal Astronomical Society of Canada.

days each, with a short month of five days thrown in between the twelfth month and the beginning of a new year, making in all 365 days.

On the other hand, the Babylonians or Chaldeans accomplished a great deal more in the science of astronomy. The early Babylonians were peculiarly impressed with the importance of the Moon. The Temple of Ur, known as the famous Temple of the Moon, on the lower Euphrates, recently uncovered by archaeologists, is thought to date before 3000 B.C. This temple was devoted to the worship of the Moon and was probably closely connected with the study of astronomy, which made its first progress with the Chaldeans. It is known that religious ceremonies used to attend the rising of the new moon, the time of full moon, and the time of disappearance. There were shrines—like the temple of Tiras in Lazas—specially consecrated for that purpose. The lunar month was a measure of time for these people. That no doubt explains the recorded great age of Noah, 962 years, and other patriarchs. In later times the solar year was related to the moon. Twelve lunar periods of thirty days each made up approximately a solar year, and every sixth year an extra month was added to adjust their calendar. This adjustment did not, according to some accounts, take place exactly every six years. If such were the case, these early people had the idea that the solar year was slightly greater than 365 days. The year dated from the new moon next before the vernal equinox. The two rivers reach flood tide about March 21st, with no marked signs of regularity as was the case of the Nile. Twelve seemed to be a number of great importance among these people. It was the Babylonians who divided the Zodiac into twelve signs. The duodecimal system of counting took precedence with the Babylonian mathematicians over the more primitive decimal system.

On March 21st and September 21st the periods of day and night are equal. The Babylonians divided each into six double hours; he said "six kasbu night and six kasbu day," thus making twelve double hours in a day. For further dividing the day into shorter periods of time he made a water clock, a primitive form which is still in use on the Malay coasting boats. It consists of a cocoanut shell with a small hole drilled in it and allowed to float in a vessel

of water. As the water rises, it gives a measure of time. By its means at the time of the vernal equinox, March 21st, they measured the amount of water that passed through this water clock, while the sun's disc rose above the horizon. This amount of water was compared with the amount of water escaping between two successive sunrises. It was found that 720 times more water escaped from sunrise to sunrise than for the sun's disc to appear above the horizon. That is, according to this primitive method, it took the sun 720 times longer to complete its whole path in the sky than to rise above the horizon. Hence one kasbu or double hour as a unit of time is equivalent to sixty suns placed side by side along the sun's path. This is our first reference to the number sixty. The hour was 60 minutes, which they again divided by a factor of sixty giving the second. It is interesting in this connection to note that the mean diameter of the sun from present observations is two and thirteen one-hundredth minutes of time and also for the latitude of the Babylonians the sun would take about two and two-tenth minutes to appear above the horizon. Our present system of time units is therefore due to the Babylonians. The Brahams, for example, counted their day sixty hours long, twenty-four minutes to an hour. Our week of seven days can trace its origin to these Babylonian people of 3000 B.C.

In 742 B.C. we have our first record of a sun dial as a means of telling time. There seems little doubt that they existed before that date. In 400 B.C. the sand-glass, commonly known as an egg-timer, first appeared. This was introduced in eastern countries where water was at a premium. Later it was used in law courts to time orations, but its chief use was in navigation to determine a ship's speed. The nautical term "knot" was developed from the idea that 47.29 feet of rope passed from the ship while the sand-glass registered 28 seconds.

(*To be concluded*)

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

Dr. Aitken appointed Associate Director

When Director Campbell of the Lick Observatory accepted the appointment of President of the University of California he stipulated that he should be allowed to continue Director of the Observatory and that an Associate Director should be appointed to attend to the details of administration. Dr. R. G. Aitken, who has been for many years an efficient member of the staff and who is now our leading authority on double stars, has been appointed to the new position.

Honours for Director Plaskett

A short time ago Director J. S. Plaskett, of the Dominion Astrophysical Observatory, Victoria, B.C., received the distinction of being elected a Fellow of the Royal Society (of London); and at the recent Commencement of the University of Toronto he was further honoured by being given the honorary degree of D.Sc. The ceremony took place on June 7, and when presenting the candidate for the degree, Sir Robert Falconer, the President of the University, used the following words:

John Stanley Plaskett

Another eminent man of science, but this time one for whom Canada herself was able to provide a position in which he has shown his commanding abilities. He graduated with honours from this University in 1899 and joined the Dominion Observatory at Ottawa shortly after its establishment. Recognizing the need of better instrumental facilities, he urged the construction of a large reflecting telescope, larger at the time than any in existence, and chiefly through his advocacy of it the Dominion Government authorized the establishment of the Astrophysical Observatory at Victoria with its magnificent equipment.

In the five years since it was completed Mr. Plaskett, assisted by three other able graduates of this University, has made many important contributions to science which have brought distinction to himself and to Canada; especially may be mentioned his recent discovery of an immense pair of suns in the constellation Monoceros (the Unicorn) which are so distant that light requires 10,000 years to come to us, which have a temperature of about 30,000° Fahrenheit, which move in their orbits with a speed of about 150 miles per second, and which are the most massive known, each being about 75 times as massive as our sun.

Mr. Plaskett's name had already been presented to the Committee on Honorary Degrees before the good news came that he was elected a Fellow of the Royal Society of London, a confirmation of our own opinion of his worth and attainment.

Professor Barnard's Paper on "Photographing the Sky"

In March, 1920, Professor Barnard visited Toronto and addressed the Empire Club at its noon luncheon and a meeting at the University in the evening. On both occasions his subject was astronomical photography, on which he was our greatest authority. The Empire Club last autumn published the address delivered before it, and as one of Prof. Barnard's objects was to give assistance to the project of providing a creditable observatory for Toronto, in which the Society has taken an active part, it was thought that the address might very appropriately be printed also in this Journal. To this proposal the Empire Club cordially assented and also supplied the blocks for the illustrations. The long-hoped-for observatory is not yet in sight, but its supporters feel that it is such an outstanding need that means for its erection will surely be forthcoming before long.

In the March issue of the Journal appeared a brief account of Barnard's life by his colleague, Professor Parkhurst. In it, reference was made to the influence on his life produced by one of Dr. Dick's works which was "wished on" him by a ne'er-do-well acquaintance in security for a small loan which Barnard had not the heart to refuse. The fullest account of the incident is given in the paper on "A Visit to the Home of Dr. Thomas Dick" by the late Dr. John A. Brashear, printed in this Journal in vol. 7, 1913. It is given in the words of Barnard himself though without his name, and it is so interesting that I feel justified in reprinting it.

> I can recall when I was a small child lying out in the open air in an old wagon bed, flat on my back on pleasant summer nights, watching the stars. I soon knew the sky thoroughly as the seasons came and went. When they came around again, I would recognize the various groups of the brighter stars, though the names of these stars and what they really were did not come to my knowledge until much later in life.
>
> I got to know the stars so well that when the seasons advanced and they slowly passed from view in the direction of the sun I would miss them as I would have missed a friend; and when they again came round, I welcomed them as I

would welcome that friend who had been absent for many months. Even to this day this same friendship with the stars still holds, and I look forward to their return with great pleasure, just as I would in the case of an absent loved one. The coming of the Pleiades, of Orion, or of the Scorpion I hail each year with the welcome of a friend.

So my interest in the stars as a child, though it was an unintelligent one, was nevertheless a pleasant one to me and helped to soften the sadness of my childhood. I had longed to know something of the heavens; but the information I got was little and not accurate, and I groped along thus until one night, while poring over some old books on mathematics which I had purchased second-hand and perhaps not wisely, a young man came to my room where I lived alone in the top story of a high building in the city. We had been children together, but as a boy he stole, and when he got older the law often laid its hands upon him. On several occasions I had helped him out from my meagre earnings, for my sympathies were easily worked upon. At one time I had paid his fine when a policeman brought him around where I was at work. On this night in particular I was in no mood to be gracious; for he had come to borrow money from me, which I knew from previous experience would never come back. As security for the return of the money he had brought a large book. This I refused to look at; and finally, to get rid of him, I gave him two dollars (which was the amount asked for). I never saw him or the money again.

Shortly after he had gone I noticed that he had left the book lying upon my table. I felt very sore, because the money was a large amount to me then, and it was some time before I would open the book. It proved to be a volume of the works of the Rev. Thomas Dick. The greater part of the book was devoted to astronomy; and it was illustrated by, among other things, a number of small charts of the stars, giving their names and how to find them in the sky. These were the first charts I had ever seen. It was but a few minutes until I was comparing these with the sky from my open window, and in less than an hour I had learned the names of a number of my old friends; for there was Vega and the stars in the Cross of Cygnus and Altair and others that I had known from childhood.

That was my first intelligent glimpse into astronomy. It is to be hoped that my sins may be forgiven me for never having sought out the rightful owner of that book in all these long years.

C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

May 1.—The regular fortnightly meeting of the Society was held in the Physics Building at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

It was moved by Mr. Hunter, seconded by Dr. Chant, that Dr. R. J. McDiarmid be the representative of the Society at the Meeting of the Royal Society of Canada.

Mr. Harold Bibby, Meteorological Office, Toronto, was nominated for membership.

Mr. Collins drew the attention of the Meeting to the results obtained by the Lick Observatory Eclipse Party, which support very exactly the result predicted by Einstein. Mr. Hunter compared last year's results with those obtained in 1919, and suggested that the difference in the results might be caused partly by the difference of the regions in which the two eclipses occurred. That in 1919 took place when the sun was in Taurus near the Hyades and hence in the Galaxy. In 1922 the sun was in Virgo in the neighbourhood of the Galactic Pole. Dr. Chant explained some of the difficulties met with in measuring the shifts of the stars, and how the measurements were actually made; he also showed how some were given a higher value than others because of the greater accuracy with which they could be measured.

In answer to a query concerning the report that the radiation from the sun was diminishing, Dr. Chant explained how these measurements were made in Arizona and in Chili, S. America. He showed how the slight diminishing of the Solar Constant would probably have little noticeable effect on the weather, which was governed more by local conditions.

Mr. J. H. Horning then described some examples of the practical work in the elementary courses of the Department of Astronomy of the University.

The uses of celestial globes for various purposes were demonstrated, some examples being: to find what stars are visible at any time at any place; to learn where the planets are at any time; to measure the lengths of day and of twilight. The globe was set for Toronto and the time chosen was the time of the meeting, May 1st at 9 p.m. The simple method of finding the latitude by means of the shadow cast by the gnomon was demonstrated and the mean result of the 1923 class of 43° 39′ for the latitude of Toronto showed that by this method very good approximate measurements could be made.

The measurement of the diameter of the sun by the simple measurements of the diameter of its image formed by sunlight passing through a pin hole and the distance of the image from the pin hole was explained. The average class result for the past session again showed a measurement of 875,000 miles. Plani-

spheres and Sundials constructed by members of the class in Astronomy were exhibited and their uses explained.

Dr. Chant supplemented the descriptions of Mr. Horning by giving some further examples of the work and by explaining the purpose of the course in spreading a general knowledge of methods and the nature of the quantities rather than the making of measurements of extreme accuracy.

J. H. HORNING, *Recorder.*

AT OTTAWA

January 25.—The first lecture of the series arranged by the executive of the Ottawa Centre for 1923 was given on January 25th by Professor C. A. Chant of the University of Toronto. The subject of the lecture was "The Einstein theory and the Australian eclipse."

In his introductory remarks Professor Chant stated that he felt quite at home in Ottawa. He had been employed in the Finance Department in the East Block for over a year, and many of his former students were now employed in the Observatory and other branches of the Government service here. The Right Hon. Arthur Meighen was one of his pupils at Toronto.

The chief object of the eclipse expedition was to make a test of a quite definite prediction that had been made on the basis of the Einstein Theory. While the speaker stated that he would not attempt to explain the theory, he pointed out that if it is correct we would have to remodel our concepts of time and space. According to Einstein, light passing a massive body like the sun should be deflected in its course by an amount sufficiently large to be capable of measurement by very accurate observations. An eclipse of the sun afforded a suitable opportunity for the determination of the predicted deflection.

To investigate the deviation of the light a portion of the sky near the sun was photographed at the time of the eclipse and the position of the stars in this photograph was compared with the photographic position of the same stars when the sun occupied a different position in the sky. The photographs required for the purpose of comparison were taken at Tahiti during the months of May and June by Dr. Trumpler of Lick Observatory.

The comparison of the photographic plates was a long and tedious process. The plates were being measured at the Victoria Observatory by Dr. Young and Mr. Harper.

Many interesting features of the 16,000 mile journey from Toronto to the eclipse camp at Wallal were described and illustrated with a selection of beautiful lantern slides. The setting up of the apparatus and the manner in which it was used in making the eclipse observations was very clearly described in detail.

The lecture room of the Victoria Memorial Museum, where the meetings are now held, was filled with an audience of well over 350 people—one of the largest on record.

The President, Dr. R. J. McDiarmid, was in the chair. The Hon. J. G. Turriff was elected to membership.

Dr. Chant has since announced that the displacement of star images is measurable and amounts to 1.7 seconds of arc, which agrees with the amount predicted by Einstein.

February 13.—Dr. R. J. McDiarmid of the Dominion Observatory gave an address on "Astronomy—a National Necessity." The speaker brought out many points of great interest in the very early history of astronomy. The origin of our units of time was explained and attributed to the Babylonians. Reference was made to early methods of recording time by water-clocks, sun-dials and sand-glasses. Following Galileo's discovery of the pendulum the first pendulum clock was constructed by Huygens in 1654. The requirements of navigation led to the founding of the Greenwich Observatory in 1675.

The meridian circle and the manner in which it is used to determine the time were described. The relation of astronomy to navigation, surveying and the fixing of international boundaries, etc., was pointed out and it was shown that to a large extent modern development has been dependent upon the practical application of astronomy.

Mr. C. R. Coutlee, the Vice-President, occupied the chair.

A. H. MILLER, *Secretary*.

The Royal Astronomical Society of Canada

(OFFICERS FOR 1923—REVISED TO MAY 1ST, 1923)

Honorary President—HON. R. H. GRANT, Minister of Education for Ontario.
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